SEQUENCING BATCH REACTOR(SBR) FOR THE BIOLOGICAL TREATMENT OF DAIRY WASTEWATER

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Abstract : The dairy industries process the raw milk products and convert them to consumer milk, butter cheese etc. In these processes a large quantity of pure water is utilized throughout the manufacture and clean-up process. The waste water generated from these process operations will have high BOD as the waste is mainly organic in nature. Here in this study Sequencing Batch Reactor (SBR) was employed in biological treatement the wastewater from a diary industry. The reactor was made of poly acrylic material with a volume was 20L. The reactor was fed with both the raw wastewater and synthetic wastewater under different environmental conditions. The reactor was also supplied with oxygen using an air sparger. A maximum of 91% COD removal efficiency was achieved by varying the COD concentration from 500 to 2500 mg/l. The optimum dissolved oxygen concentration in the reactor was found to be 2.4 mg/l and MLVSS was 2950 mg/l. From the study conducted using this reactor it was found that the SBR was predominantly suited well for the biodegradation of wastewater in the diary industries.

***IndexTerms* - Sequencing Batch Reactor, Biological Treatment, Dairy Wastewater, Biodegradation .**

I. Introduction

Nature conservation and improvement of the environment is one of the most considerable problems of the modern world. An important component of the environment is the water whose quality is the basis of the balance of ecosystems. In the recent development of urbanization, tourism and industry leads to increasing of worldwide water consumption. On the other hand the volume of wastewater effluents into water intakes containing a variety of unwanted pollutants is continuously growing. Wastewater treatment before its discharging into water bodies is an important assignment of any civilized society, central and local governments. Domestic and industrial wastewaters incoming into the urban treatment plants(UTP) are characterized by irregularity in the amount and type of the pollutants. Therefore, the facilities for the treatment of this type of water are combined and typically include a mechanical, biological and in some cases, chemical step. The biotransformation of organic pollutants is carried out in the aeration tanks, where under the action of the existing biocenosis and in the presence of the required amount of dissolved oxygen in the water, the pollutants are converted into environmentally safe substances (DAVIS, 2010).

For the first time, Sequencing Batch Reactors(SBRs) technology has been used in 1914. Later in 21st century, it is becoming more and more popular due to the excellent opportunities for adaptation to seasonal changes without limitation of the required optimal treatment capacity at each load. This technology offers great flexibility in terms of the implementation and control of different phases of the biological treatment process, such as biological phosphorus removal, aerobic oxidation of nitrogen(nitrification) and anoxic elimination of nitrate(denitrification). Several studies demonstrated the effectiveness of SBR technology and its application as an alternative to conventional flow system with respect to the treatment of municipal and industrial wastewater, especially for smaller flow.

In the South Indian experience in wastewater treatment with a total biomass for complete removal of BOD_5, nitrogen and phosphorus is relatively new and limited. Recent projects for new Sequencing Batch Reactors(SBRs) are developed by mathematical models and programs. These plants are not susceptible to mathematical verification. For examination of plant's design and efficiency of operation can only be used the results from the wastewater analysis at the inlet and the outlet of the already constructed plant during its exploitation.

The purpose of this research paper is to evaluate the performance of the Sequencing Batch Reactors(SBRs) of three dairy units, which includes biological stage in aeration basins of cyclic type (SBR-method).

II. Dairy Wastewater Treatment

Dairy manufacturing has a strong impact on the environment, producing large volumes of wastewater with high organic and nutrient loading and extreme pH variations. This requires the application of effective and cheap wastewater treatment procedures which ensure fresh water preservation[1]. There are various dairymilk samples in the following fig.1. There are various dairy effluent treatment strategies (Fig.2), which are described in the following paragraphs.

Figure 1 : Milk samples from three Dairy form.

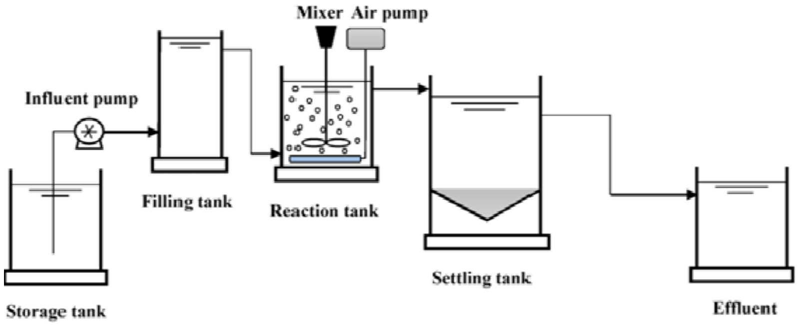

Figure 2: Sequence Batch Reactor design

1.2 Biological Treatment

One of the most reliable methods for dairy effluent purification is biological removal. Such methods can assimilate all dairy wastewater components, but they mostly utilise soluble compounds and small colloids. These processes have not been fully studied. Moreover, because of their unlimited adaptation potential, they can be jointly used in various sequences to meet certain component biodegradation requirements[2]. Biological treatment has two main branches depending on oxygen requirements: (i) aerobic and (ii) anaerobic processes.

1.3 Aerobic Processes

Nowadays, most dairy wastewater treatment plants are aerobic although they have been less efficient, mainly due to filamentous growth and rapid acidification caused by high lactose levels and low water buffer capacity, respectively[3]. Problems generally encountered with activated sludge processes are bulking and foaming, which diminish sludge settling, Fe_{3+} and CO_3 precipitation, additional biomass production as well as poor activity at low temperatures. It takes a few months for the sludge adaptation before full operational capacity is reached. Nitrogen from NH_3 is easily degraded. Phosphorus removal is less effective and relies on environmental conditions. Aerobic bacteria are less useful in colloid utilisation, when compared to anaerobic bacteria. The heightened O_2 depletion(>3 kg of O_2 per kg of BOD_5) requires large energy demands during the aerobic treatment of concentrated dairy wastewater (>2 g of COD per L). Plug flow systems are better than complete-mix processes, since they are less sensitive to high organic load problems like bulking sludge,etc. Commonly, dairy effluent OLR, expressed as BOD_5, should be lessthan 0.28–0.30kg/m3. To enhance biological removal, a proper pretreatment or adequate wastewater dilution should be applied.

Aerobic biological systems give a very positive response during synthetic dairy wastewater treatment with 4g/L of COD and 1g/L of TKN at pH=11.5, with over 96% of degradation being achieved in a continuous mode. An artificial effluent similar to milk powder and butter processing wastewater was treated in an anaerobic anoxic-oxic system at HRT of 7 days and a nominal sludge age of 20 days. The process was characterised by sludge bulking due to the growth of filamentous bacteria(Sphaerotilus natans, Type 0411 and Haliscomenobacter hydrossis).TN removal remained unchanged at 66% with without the improvement in the sludge volume index. TP depended on the anoxic selector relative dimensions (from 49 to 20%) and a respective nitrate rise in the effluent. Nevertheless, more than 90% of COD reduction was achieved. Aerobic filters are applied to a lesser extent in the treatment of high-strength dairy effluents rich in FOG. High fat and heavy biofilm blockage are possible, which results in biomass loss, filter fouling and corresponding reduction in productivity. The sequencing batch reactor (SBR) is preferred in dairy wastewater treatment because of its various loading capabilities and effluent flexibility. A traditional technology with free sludge flocs is mostly applied. The purification of milk effluents is given. COD was reduced by 91–97,TS by 63, volatile solids(VS) by 66, TKN by 75, and TN by 38%. However, mechanical treatment had to be applied first. Another study shows the aerobic SBR as an excellent example of the combination of activated sludge granulation with dairy effluent treatment. Granulation stability is limited by nutrient concentration in the wastewater, while effluent quality depends on the need for preliminary sludge settling, usually 0.25–0.5 HRT. Up to 90% of total COD, 80% of TN and 67% of TP were reached in an 8-hour cycle and 50% volume exchange ratio. The results were obtained after fully activated sludge granulation and consecutive biomass sedimentation.

The soluble effluent COD was reduced to 125mg/L. Industrial effluents are more difficult to treat than synthetic ones. The lower maximum OLRs also reduced the SBR granular sludge efficiency. In a bench-scale SBR, raw industrial dairy wastewater was treated with *Lactobacillus casei* TISTR 1500. Microaerobic conditions maintained in the SBR allow for biomass accumulation in large amounts, leading to 85% lactose reduction *via* rapid fermentation and subsequent protein coagulation by 90%. As a consequence,70% of COD degradation can be achieved. Around 2.67 times higher OLR was achieved in two laboratory aerobic SBRs treated with a mixed landfill and dairy effluent than in traditional SBR processes. The best BOD_5 removal mode was reached at OLR, expressed as BOD_5, of 0.8 kg/(m3·day) per a 10-day HRT.

The application of flexible fibre as an activated sludge carrier increases the laboratory SBR reliability and it is possible to treat dairy effluents at very high OLRs. At OLR, expressed as COD, of 0.4kg/(m3·day), COD was degraded by more than 89% and up to 97% at OLR, expressed as COD, of 2.74kg/(m3·day). Membrane technologies are successfully applied in the treatment of low-load dairy effluents in an SBR. A high BOD removal (over 97%) and TSS-free wastewater are obtained. Due to low influent loading, TN removal reaches 96% by means of assimilation only. TP elimination reaches only 80% after system optimisation due to the limited excess sludge disposal.

Good results can be reached in a membrane bioreactor during the treatment of an ice-cream factory effluent with 13.3kg/m3 of COD, 6.5kg/m3 of BOD_5 at a temperature of 25°C. Both indicators are reduced by over 95%, while TKN is decreased by more than 96 and TP by 80%. Under aerobic conditions, the indigenous microflora composed of lactic acid bacteria may reach over 109CFU/mL, which will downgrade CIP-induced alkaline pH variations.

Various alternatives for aerobic treatment of dairy effluents are also used. Pure oxygen is another possibility in the biodegradation of milk wastewater. Oxygen can be applied directly in the homogenisation tank during a traditional physicochemical treatment and stable operation is achieved under a broad initial COD and TSS range. This modification improves effluent quality and reduces process costs. Such oxygen injection systems can replace the expensive anaerobic treatment and are naturally safer. Cheese whey can also be successfully utilised as a cheap medium for edible mushroom cultivation. Some authors report the growth of *Ganoderma lucidum* on protein-free cheese whey. The best soluble COD utilisation was achieved at pH=4.6 and 27.1°C, while the maximum mycelial yield of 0.35 mg per mg of soluble COD removed was obtained at pH=4.2 and 28.5°C. Although there is information on edible fungal growth, dairy wastewater utilisation has not been studied from a COD point of view.

1.4 Anaerobic Processes

Anaerobic systems are more suitable for the direct utilisation of high-strength dairy wastewater and are more cost-effective than aerobic processes. If properly operated, these systems do not produce unpleasant odours. The major problems of anaerobic dairy wastewater treatment include long startup periods due to complex substrate degradation, preliminary biomass adaptation prior to protein and fat utilisation, fast drop in pH and a resultant inhibition of methane production, sludge disintegration by fats in the form of triglyceride emulsions and subsequent biomass flotation, presence of inhibitory compounds (long chain fatty acids, K+ and Na+ ions), inability of ammonia biodegradation and phosphorus removal, careful management, increased sensitivity to various OLRs and shock loadings, *etc*. Notwithstanding the little information on industrial-scale anaerobic plants utilising cheese whey, more than 75% COD removal and around 10 kg/(m3·day)of OLRs, expressed as COD, are achieved. The degree of biodegradation depends on the HRT applied.

Milk processing effluents are predominantly treated in conventional one-phase systems: upflow anaerobic sludge blanket (UASB) reactor and anaerobic filter (AF) are most commonly applied. UASB reactors have been used in industrial dairy wastewater treatment for more than 20 years. They are suitable for treatment of overloaded effluents with COD higher than 42g/L. Laboratory scale UASB reactors utilising whey permeates in a continuous regime have been designed. Kinetic coefficients using the Monod equation are determined per HRT of 0.4–5 days and an initial wastewater COD of 10.4–0.2g/L. It was shown by a comparative study of the possibility of using flocculent sludge and the effect of different HRTs (6–16h) on the anaerobic UASB reactor behaviour applied to dairy wastewater treatment that nearly 80% of protein mineralisation, soluble COD and volatile fatty acid degradation as well as over 60% fat removal can be reached at an HRT of at least 12h and an OLR, expressed as COD, of less than 2.5g/(L·day). Biomass granulation was also achieved in the UASB reactor within 60–70 days. Of all the elements studied, only Ca_{2+} ions had any significant effect. When treating a synthetic ice-cream effluent in the UASB reactor, TOC was reduced by 86% at an HRT of 18.4 h, with the highest OLR, expressed as TOC, reaching 3.06kg/(m3·day). High FOG degradation is also possible in an UASB reactor. A couple of bench-scale UASB reactors were successfully employed during the utilisation of a synthetic milk effluent rich in FOG(0.2, 0.6 and 1g/L). Enzymatic pre-hydrolysis contributed to 8% more COD removal at the highest FOG concentration. Cheese effluents are degraded in UASB reactors in laboratory tests and on an industrial scale. A laboratory-scale UASB reactor utilising a cheese factory effluent eliminates around 90% of effluents at an OLR, expressed as COD, of 31 g/(L·day). Organic loads, expressed as COD, over 45 g/(L day) perform worse (70–80% only). Moreover, chemicals are needed to support a constant pH. Short-shock OLR during operation increases sludge granulation, improving stability in reactor performance.

The results of the laboratory tests on an industrial level have been confirmed, improving them by 6% per 10% higher load. A full-plant UASB reactor can be applied in cheese factory wastewater treatment. With an initial COD of 33 g/L, HRT of 16h and OLR, expressed as COD, of 49.5 kg/(m3·day), 86% degradation can be reached. During the utilisation of an industrial effluent from Edam cheese, butter and milk production, a full-scale UASB reactor can be applied, the COD being decreased by 70%. Dairy effluents with a low TSS can be successfully utilised in AFs in an all-scale range. The COD decreased by between 60% and 98% at a HRT of 12–48 h and an OLR.

2. Literature Review

U.B.Deshannavar et.al.[4][2012], have studied the upflow anaerobic fixed bed reactor for digestion of dairy industry effluent using polypropylene pall rings as a packing media and found that average COD removal efficiency of 87% and maximum biogas production of 9.8 l/d was achieved.

T.Ramesh et al.[9][2012]has studied a Fixed Film and Fixed Bed Anaerobic Reactor for treating Dairy Waste Water and found that COD reduction is a maximum of 80.88% for a varying influent COD from 1500 to 4700 mg/lit. for the OLR of 0.004 kg COD/m2/day and HLR of 0.003 m3/m2 .day. The maximum gas conversion ratio is 0.265 m3 of biogas per kg of COD removed.

Sathyamoorthy G.L et.al[8][2012] have studied the performance of the anaerobic hybrid reactor(AHR) which is a combination of Upflow anaerobic sludge blanket reactor(UASBR) (suspended biomass) at bottom and Anaerobic Filter Reactor (AFR) (attached biomass) at top to treat dairy wastewater. Here it is used the Bioflow®30 shape PolyPropylene(PP) inert media as the reactor filter media and revealed that the Anaerobic Hybrid Reactors(AHRs) were effective in the treatment of low-strength dairy wash-water giving 85% COD removal for an OLR of about 4.2g COD/L.d and HRT of 0.9d. in BOD, COD and VSS of dairy wastewater in batch and repeated batch cultivation systems. Here it is found that the efficiency of COD removal is associated with the nature and properties of support material. Eventually, the maximum percentage removal of COD, BOD and VSS turned out to be as 96%, 93% and 90%, respectively, with the application of 21Kg COD/m3/d loading in batch reactor filled with gravels.

Deshpande D.P. et.al. [8][2012], have used the Upflow anaerobic packed bed bioreactor (UAPB) with an internal diameter of 20cm and a height of 45cm using seashell as a packing material for dairy wastewater treatment. He used the UAPB not only for treatment but he proved that with the help of UAPB dairy industry effluent is very good raw material for production of methane gas, commercially known as BIO-GAS, which can be use as a fuel and can replace the other fuel and COD value also decreases from 71526mg/lit to 42200mg/lit as the time increases from first day to the 56th day of the experiment.

J. I. Qazi et.al[6] [2011] has studied a number of biofilm support media including foam cubes, bamboo rings, fire bricks, PVC rings and gravels to immobilize biomass for reduction in BOD_5, COD and VSS of dairy wastewater in batch and repeated batch cultivation system in Anaerobic Fixed Film Biotreatment. Eventually, he found that the maximum percentage removal of COD, BOD and VSS turned out to be as 96%, 93% and 90%, respectively, with the application of 21 Kg COD/m3/d loading in batch reactor filled with gravels.

Monali Gotmare et.al[9][2011]has studied a UASB reactor treating dairy wastewater and found that reactor achieved COD, BOD, TSS removal efficiency was observed 87.06%, 94.50%, and 56.54% respectively. The average gas production and methane gas conversion at optimum conditions was observed to be 179.35m3/day and 125.55m3/day, respectively.

Rana Kabbout et.al[][2011] has studied the physicochemical treatment of Sweet Whey the major pollutant in Dairy industry by coagulation-flocculation using Aluminum sulphate $Al_2(SO_4)_3$ as a coagulant because it reduce the hardness and the load of phosphate in the wastewater and found that 33% of the chemical oxygen demand, 45% of the turbidity, 72% of suspended matter and 20% of total phosphorus gets reduced.

G.Srinivasan et.al[7][2009] have carried out experiments on Anaerobic Diphasic Fixed Film Fixed Bed (FFFB) digester in the treatment of a synthetic dairy wastewater in order to reduce the COD of dairy waste water and for the production of biogas. They have reported maximum removal of COD as 70.40% at a flow rate of 0.006m3/day for an overall OLR of 1.265Kg COD/m3 .day giving a maximum yield of bio-gas at 0.330m3 of gas/kg COD removed.

G.D.Najafpour et.al[8][2009] have used upflow anaerobic packed bed bioreactor (UAPB) to treat Dairy Wastewater. The Plexiglas reactor column was packed with a seashell, and found that high COD and Lactose removals of 94.5% and 99% at HRT of 16h having highest yield of methane production and the maximum biogas volumetric production.

G.D. Najafpour et.al[6][2008] have used Upflow Anaerobic Sludge-Fixed Film (UASFF) Bioreactor for the Treatment of Dairy Wastewater. UASFF bioreactor was developed with tubular flow behavior in order to shorten the startup period of UASB reactor at low HRT. In this treatment; the column was randomly packed with seashell and at HRT 48h and temperature 36°C found that, the COD removal rate and lactose conversion of 97.5% and 98% respectively.

A.Arumugam et.al[5][2008] have used a three phase fluidized-bed bioreactor (FBBR) for the aerobic treatment of dairy wastewater using culture of living cells immobilized on support particles of ceramic, Teflon, glass supports were studied and found that percentage reduction in COD for ceramic, Teflon and glass particles are 91%, 85% and 78%, respectively.

P.Sankar Ganesh et.al[4][2007] have studied the dairy industry wash water treatment by UASB reactor and reveals that about 75-85% of COD was removed from dairy wash waters coming into the UASBs at COD concentrations of 1200-2000 mg/L at 6h HRT. This means that the wash water exiting from the UASBs have COD in the range 180-500 mg/L. Such dilute effluents can be easily and quickly polished by short duration (1-2h)aeration.

In this research would like to use fixed film fixed bed reactor using coir as a support media to treat the dairy industry wastewater which would be at lowest cost and is beneficial to industries. Sequential Batch Reactor(SBR) offer the advantage of high-load systems, requiring much less volume and space, and hence less investment as compared to conventional systems. Furthermore, these systems tend to operate more stable under transient conditions, like fluctuations of substrates and pH. Such advantages are of interest to those industries which produce large amounts and/or highly concentrated wastewaters, notably the milk industries.

3. MATERIALS AND METHODS

3.1 Study Area

The study was conducted in 3 dairies in south India with processing capacity of 700000, 100000, and 500000 litres per day in each dairy named as Dairy-I, Dairy-II and Dairy-III. As instructed by the Dairy authorities and as directed by the experts, it is unable to provide the name of the Dairies along with the data. The study was carried out during the period of January – December in the year 2018.

3.2 Methodology

Sampling was done as per standard methods prior to the treatment and after treatment of waste water[APHA]. Analysis for BOD and COD were carried out in all samples in accordance with standard procedures and BOD5/COD ratio was determined. This includes determination of ranges and mean values of biodegradability indices in an attempt to make a kind of zoning for the BOD/COD ratio (biodegradability index)[6]. The test results were tabulated for detailed analysis and interpretations.

A bench scale sequencing batch reactor(SBR) was fed by wastewater from milk factory. The reactor was constructed from plexi glass with a volume of 20L. The reactor was supplied with oxygen by fine bubble air diffuser. In the first phase, the reactor was operated with total cycle time of 7 hrs. The second phase of the experiments was run under different dissolved oxygen concentrations of 5, 6.5, and 7.5 mg/L. In the third phase the reactor was conducted at different COD concentrations of 1500, 2000, and 2500 mg/L. All analyses were performed according to the procedures outlined in Standard Methods ((APHA, AWWA,WEF, 1995).

4. EXPERIMENTAL RESULTS

In order to determine the COD removal efficiency by SBR, the reactor was operated at 8 hrs cycle time and influent COD varied from 520 to 2500mg/L. The performance of reactor in this phase under these conditions is shown in Table 1 which demonstrates that, more than 90% COD removal efficiency was achieved in the reactor with mean influent and effluent COD concentrations of 835 and 42 mg/L, respectively.

Table 1: Performance of reactor in first phase

Parameters		Range of concentrati	Mean of concentratio	Number of observatio
Influent COD	(mg/L)	520-2500	835	12
Influent BOD	(mg/L)	442-1487	955	8
MLSS	(mg/L)	3350-4200	3250	10
MLVSS	(mg/L)	2655-2880	2950	10
Effluent COD	(mg/L)	39-49	44	12
COD removal	(%)	90-92	91	12

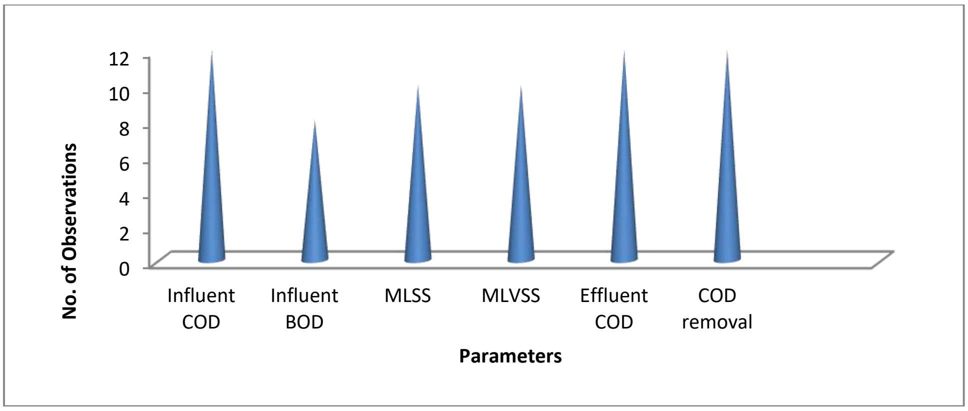

Figure 1: Performance of reactor in this phase under these conditions

In the second phase, the reactor was operated at different aeration times to evaluate oxygen effect on the removal efficiency and settling of sludge. Fig. 1 shows the effect of aeration time on COD removal, based on which, the optimum aeration time was 6 hrs. As shown in Fig. 1, COD removal efficiency increased with rising aeration time up to 6 hrs. No significant COD removal efficiency was observed when aeration was applied more than 6 hrs. Fig. 2 illustrates the sludge settling under different dissolved oxygen concentrations. From this Figure, the optimum dissolved oxygen concentration for best sludge settling was 3 mg/L. Increasing dissolved oxygen more than 3 mg/L resulted poor sludge settling conditions. Apparently, no significant COD removal efficiency was achieved with the increase of MLSS concentrations. The MLSS concentrations of the SBR reactor varied from 3000 to 9000 mg/L during the study.

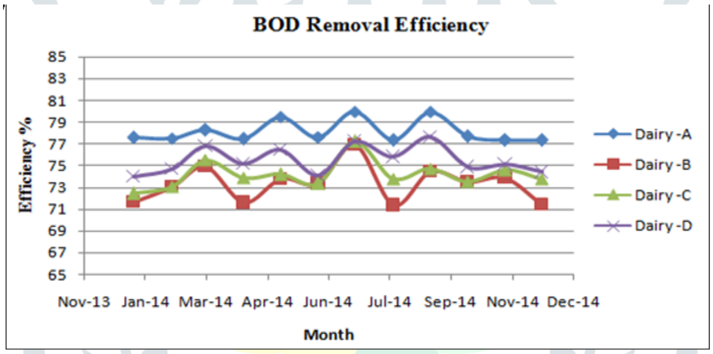

Fig. 2 Comparison of BOD Removal Efficiency

In the third phase the flexibility of the reactor to high COD concentration was evaluated.

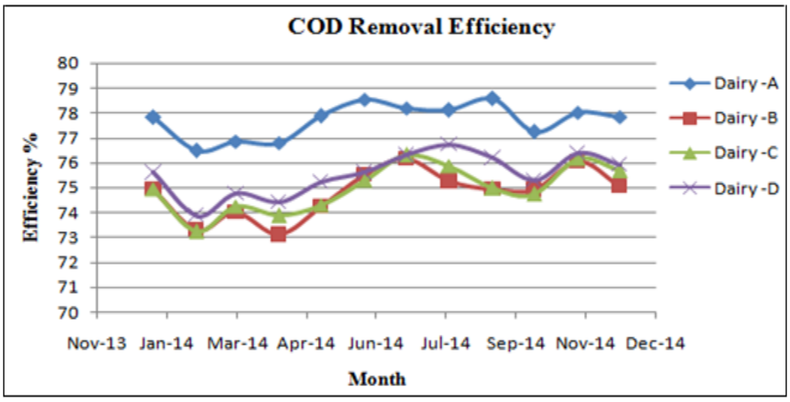

Fig. 3 Comparison of COD Removal Efficiency

The reactor was operated under different COD concentrations in the range of 1000 to 2500 mg/L, whereas dissolved oxygen, time of aeration and MLSS were kept constant and equal to 2-3 mg/L, 6 hrs and 3000 mg/L, respectively.

5. CONCLUSION

In conclusion it may be stated that Sequence Batch Reactor (SBR) treatment need to be done chiefly due to this reason.

1. To avoid the ill effect of discharged untreated effluent into the environment.
2. To satisfy the statutory requirements of the state pollution control board and central pollution control board.
3. In realization of our commitment to the future generations to provide pollution free environment.
4. From the results obtained, it was evident that the SBR was a suitable alternative for Dairy and other industrial wastewater treatment.
5. The results from this study proved the SBR flexibility and excellent performance for treating domestic and easily biodegradable wastewater such as dairy wastewater.

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